Chapter 6
Chemical Dosage for Wells

Chemical treatment in a preventive mode is a major aspect of maintenance of well and fluid system performance. ASTM D 5978, which addresses the maintenance of monitoring wells, does not recommend the use of chemicals, but redevelopment only. This restrictive guidance is not extended to pumping and injecting wells on HTRW sites, for which the responsible use of chemicals in PM redevelopment is usually needed to improve the well's effectiveness. Experience shows that chemical choices in well treatment are often made based on incomplete information or vendor sales literature. And while information should not be dismissed if it comes from a commercial source (as vendors frequently seek to educate), it is crucial that personnel engaged in the planning of well system O&M seek expert advice and review publications specifically written for these types of sites to become well acquainted with the features of chemical choices, both for effectiveness and safety.

6-1 Lists of Chemicals to be Used

a. Issues in chemical choices. The listings of chemicals in this section include brief summaries of the chemicals' uses. Detailed information is provided in Borch, Smith, and Noble (1993), ADITC (1997), and Smith (1995).

(1) Reactivity with constituents of contaminated ground water is an issue in HTRW remediation and monitoring well maintenance. Table 2-4 provides a summary of common reactions.

(2) Cost is frequently cited as an issue in choices made as to whether to use chemicals and electing which ones and how much to use.

(a) Three factors affect the market price of chemical products used in well cleaning:

- Actual process and shipping costs.
- Premiums for purity and standard certification.
- Degree of commercial exclusivity (particularly with proprietary products).

(b) In terms of effectiveness, a more expensive chemical may be a better choice and therefore cost-effective. Among the acids, for example, organic-based and more concentrated products are more expensive than inorganic acids, primarily due to process costs. However, their effectiveness against biofouling and relative handling safety may outweigh the actual material cost differential.

(c) The USACE directs that HTRW site project and O&M management take a "long-view" approach to O&M cost-effectiveness calculations, i.e., to consider cost-effectiveness on a life-cycle cost basis. Available research (Sutherland, Howsam, and Morris 1994) in water supply applications indicates that even aggressive PM is cost-effective compared to losses in efficiency, equipment repair, and well failure. HTRW ground water plume management adds the factor of the project mission, i.e., the cost of failure to control contaminated ground water.

(d) Warning. The chemicals used in O&M are all reactive and pose risks to skin, mucous membranes, and other soft tissues of humans, and are potentially harmful to the environment if handled improperly. They should only be used by trained personnel familiar with their safe use, and who are equipped with proper respiratory and skin protection. Material Safety Data Sheets (MSDS) and other safety information must be reviewed by all personnel involved (mandatory). No HTRW remediation

project should employ personnel or contractors to perform well cleaning who cannot clearly demonstrate competence in use of, and a thorough understanding of the potential reactivity between well cleaning chemicals, contaminants of concern and other chemicals present on the site.

b. Chemical classes and properties. The following paragraphs summarize chemical purposes and effects, safety, handling, and effectiveness features.

(1) Acids. Acids are used to dissolve hard encrusting materials, including Fe and Mn oxides and carbonate deposits. Tables 6-1 and 6-2 list acids most commonly used in well rehabilitation. Table 6-1 lists recommended compounds. Table 6-2 lists commonly used well cleaning compounds not recommended by the USACE for HTRW well PM treatment.

Table 6-1. Recommended Acid Compounds

Acid	Descriptors	Safety & Handling
Acetic acid	Excellent biocide and biofilm dispersing acid. Relatively safe to handle. Often a major component of biofouling "enhancers" and brand-name mixtures specified for biofouling. Acidizing to pH < 2 with sulfamic acid recommended (rapidly loses acid power without). Should use food or good industrial grade > 85 % acid. (variation: glycolic or hydroxy-acetic acid).	Safety: Use gloves, splash protection, and respirator at barrel end*. Does not require placarding for shipment.
		Handling: These solutions freeze at working ambient temperatures: glacial at 10^o to 12.8^o C (50^o - 55^o F), 84% at 4.4^o C (40^o F), 15% (working solution) ~ 0^o C (32^o F). Make the dilution at an ambient above the stock solution freezing point.
Sulfamic acid	Relatively effective against carbonate scales, and as an acid enhancer for acetic acid. Not effective alone against biofouling or metal oxides.	Safety: Relatively safe to transport and handle (solid, dust inhalation should be avoided).
		Handling: Solid, less aggressive than HCl (Table 6-2). Use gloves, dust mask and goggles. Provide proper ventilation. Circulate during mixing.
Other organic acids	For example, oxalic and citric acids. Useful as chelating agents. Oxalic acid is also effective as a primary acidizer in low-Ca water. Often form insoluble precipitates in high-Ca waters.	Safety: Safe to transport.
		Handling depends on form (typically granular solids). Use gloves, dust mask, and goggles. Provide proper ventilation. Circulate during mixing.
* Refer to Chapter 7 and health and safety references.		

(2) Biocides. These agents are used in the attempt to reduce bacterial populations. As in water supply well cleaning (Borch, Smith, and Noble 1993), in HTRW well cleaning (maintenance or rehabilitation), reducing bacterial numbers is typically impractical and no longer considered a primary objective (Smith 1995; Alford and Cullimore 1999). The reduction of hydraulic impact and other symptoms for the longest time possible is the primary objective.

(a) Chlorine (typically sodium or calcium hypochlorite (AWWA Standard B300)). Sodium hypochlorite is liquid and more likely to retain solubility in high total dissolved solids solutions. One procedure used to limit and remove biological encrustation is termed a "shock" chlorine treatment. Standard ANSI/AWWA C654-97 covers the procedures for shock chlorination and bacteriological testing for the disinfection of wells for potable water service. Well cleaning maintenance and rehabilitation are not standardized but methods are available (Borch, Smith, and Noble 1993). Concentrations as high as 500 to 2,000 mg/L of chlorine are usually desirable for this. This is NOT RECOMMENDED for HTRW maintenance treatment applications. Chlorine is a powerful oxidant that reacts with organic compounds, causing chemical alteration of the compounds to more difficult-to-treat forms or to potentially explosive situations with eruption of chemicals at the surface. This latter reactivity, particularly in light of the carcinogenic properties of some chlorinated organic compounds, is the basis for increasing regulatory scrutiny of the use of chlorine for purposes other than maintaining potability of water.

Table 6-2. Common Well Cleaning Chemicals in Use -- Not Recommended

Acids	Safety Concerns*	Effectiveness
Muriatic acid (HCl)	WARNING: Extremely hazardous to handle. Volatile liquid: Requires respiratory and splash protection.	Powerful for removing mineral and inorganic metal oxide scale. Relatively ineffective against biofouling and deleterious to stainless steel (CEGS 13405).
	DO NOT mix with chlorine reaction in well can lead to surface eruption of chemicals and Cl gas; use inhibitors for metal well screens but note that some industrial inhibitors should not be used in potentially potable ground water (toxicity), and gelatin (safe) provides nutrient and inoculum for regrowth.	Steel industry pickling liquor by-product. Quality is a problem, with cadmium and other impurities often present in industrial grades, although NSF 61** certified solutions are available. NOT RECOMMENDED for maintenance treatments.
Phosphoric acid	WARNING: Extremely hazardous to handle. A strong food grade quality acid, readily available, 75%, in 208 liter (55 gal) drums and 45.4 – 56.8 liter (12-15 gal) containers.	Effective against metal and mineral hydroxides. Somewhat effective against biofouling, but no more so than some other mixtures.
	Quite hazardous to handle. Full breathing mask and splash protection required. Adequate ventilation a must.	Leaves phosphate residue behind for bacteria. NOT RECOMMENDED for maintenance treatments.

* Refer to Chapter 7 and health and safety references.
** NSF International Standard 61 covers the safety of chemicals for human contact.

(b) Ozone. Ozone (O_3) is formed by exposure of oxygen O_2 to strong electrical charges. Ozone has to be generated at the point of application due to its instability, which precludes storage under pressure or transport, making it largely impractical for rehabilitation. Ozone does not have a recognized practical application in well maintenance treatment, although it may be used in piping system treatment to repress biological activity (CEGS 13405 and EM 1110-1-4008).

(c) Hydrogen peroxide. Like ozone, aqueous hydrogen peroxide is a powerful disinfectant and oxidant. It has been used with some effectiveness in removing well biofouling in both water supply and environmental wells. There are a variety of sources of "generic" 50% peroxide mixtures available commercially. It should also be noted that H_2O_2 is aggressively attacked by bacterial enzymes. It breaks down to form H_2O and O_2, and the resultant oxygenation can actually enhance microbial growth away from the well and the lethal oxidant zone. It may be used in piping system treatment to repress biological activity. (CEGS 13405 and EM 1110-1-1008).

(d) Potassium permanganate. Potassium permanganate (AWWA B303), another powerful oxidant used in maintaining industrial process systems and in water treatment (CEGS 13405) for relatively uncontaminated water, is not used as a primary oxidant in well treatments. Dissolution of metals and biofilms is more effectively accomplished using acids (Section 6-1c(1)).

(e) Use of heat. In some cases, water heated to 54^{o} C and recirculated over several days is sufficient without chemicals at least in the short term. Note: Heat propagates from the application source, but typically accumulates in the well structure due to the poor thermal conductivity of soil materials. Heat can actually enhance growth away from the thermal shock zone, as well as cause drying and shrinking clays such as bentonite grout. Using heat alone is also very inefficient in terms of fuel or power to generate thermal energy. The best approach to using heat is in a process such as the blended chemical heat treatment method described below (6-1.c) with a prudent selection of chemicals (Alford and Cullimore, 1999).

(3) Sequestration. In well treatment, these compounds are most properly used in low concentrations in chemical blends as aids in acidizing mixtures to retain biofilm and metal oxide components in solution for removal, once they are dissolved and dispersed in the water column. Examples are various polyphosphates, pyrophosphates, and polyacrylamide-based compounds. In addition, acetic acid and citric acid (Section 6-1c(1)), and some proprietary acid formulations also have related chelating properties.

(a) Phosphate-containing compounds are NOT RECOMMENDED for maintenance well treatment. Residuals of the compounds themselves (higher molecular weight (MW) polymers) and breakdown products (low-MW pyrophosphate and orthophosphate or phosphate) remain behind in the formation (attached to clays). The presence of an enhanced phosphate resource induces enhanced biofilm development, often at the edge of development influence.

(b) Polyacrylamide and similar polyelectrolyte wetting agents provide the desired effects of dispersing clogging deposits and clay/silt buildup without being phosphate sources. These compounds are not readily attacked by microorganisms. They should be handled, used, and ultimately disposed of according to manufacturer/supplier and MSDS instructions.

(4) Reactivity. Consult reactivity tables (e.g., Table 2-4) for problems with ground water constituents. EM 1110-1-1008 provides guidance in system material reactivity.

c. Blended method treatments. Typically, no one chemical type will address all encrustation and biofouling removal, suspension, dispersal, and repression needs. Blending approaches can permit more effective removal of multiple problems, or treat a single difficult problem more effectively (Smith, 1995; Alford and Cullimore, 1999). Appendix C includes one scenario. The exact blend of chemicals for a particular well field situation is determined based on an analysis of the needs for cleaning the clogging materials present and ground water quality.

d. Role of development. It should be emphasized that all chemical mixtures are far more effective with adequate mechanical mixing and development, and should be specified based on an adequate analysis of the problem.

e. Purge water handling. Any purge water should be disposed of properly in wastewater treatment or surface spreading on soil. The definition of “properly” will depend on the chemical mixtures, their chemical properties (e.g., pH), and the sensitivity of the treatment or land system. Discharge to any surface waters must be avoided. Phosphate-loaded water discharged to surface waters can cause algal blooms and oxygen depletion, resulting in suffocation of aquatic animals. Additionally, pH shock is toxic to aquatic life, and turbidity can suffocate.

6-2 Use and Interpretation of MSDS

a. Requirement. Having MSDS on hand is a requirement of governing agencies (including USACE) and a central feature in safety plans involving chemical safety. The Occupational Safety and Health Administration (OSHA) requires the MSDS to accompany each container of reactive chemical from point of origin to point of consumption or final disposal. Each person handling each chemical must verify that he/she has read the MSDS, or has had it read to him/her and that he/she understands the precautions necessary.

b. Use. MSDS must be on hand to provide guidance in personnel exposure problems, reactivity concerns, and neutralization recommendations, and to provide information on basic physical properties (e.g., the relatively high freezing temperature of organic acids). The MSDS of proprietary chemical blends also permits interpretation of their contents and modes of operation in treatment.

6-3 Calculation Work Sheets

This pamphlet provides calculations for well volume dosages, and includes well volume/foot tables for common well diameters. These are found in Appendix D. Appendix C offers recipes for commonly used mixtures.